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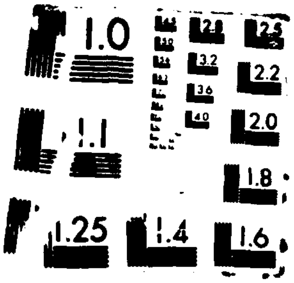
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AUTOMATICITY AND THE CAPTURE OF ATTENTION BY A PERIPHERAL DISPLAY CHANGE

by

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SUMMARY

The proposal that peripheral visual changes (cues) tend to summon attention automatically was tested by studying the effect of peripheral cueing on simple detection latency. Delay between cue onset and target onset, the contingent relationship between cue location and target location, and instructions to subjects were manipulated. Results showed that a peripheral display change could capture attention even when the target was far more likely to appear at an uncued location. When subjects were explicitly informed that targets were likely to appear away from the cued location they were able to suppress this effect, but were unable to completely reverse it by rapidly orienting attention towards the uncued side. Hence the process appears to be automatic in the sense that it occurs unless there are explicit instructions to the contrary. With explicit instructions the processing operation can be suppressed, but not completely reversed.

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1. INTRODUCTION

Visual selective attention can be aligned covertly (ie, independently of movements of the head or eyes) with locations in space. Recent studies of covert spatial attention have made use of a technique whereby a pre-trial cue informs the subject of the likely location of an impending display item. It has been found that the efficiency of perceptual processing at spatially cued locations is improved relative to uncued locations, and this has been interpreted in terms of the alignment of a covert attentional mechanism with the cued location (eg. see Posner, 1980; Posner, Snyder and Davidson, 1980). Jonides (1981) has discussed shifts of attention induced by spatial cues in relation to the distinction between automatic and controlled processing. He distinguished between the attentional effects of two different methods of spatial cueing, peripheral and central. In Jonides' experiments both peripheral and central cues consisted of an arrow-head pointing towards the most likely location for the next target. In the former the cue was presented peripherally in a position directly adjacent to the target location, while in the latter the arrow-head was presented centrally. Hence, peripheral cues signalled spatial location directly, while central cues were related to target position symbolically. Jonides proposed that peripheral cues tend to summon attention in an automatic, reflexive manner, while shifting attention on the basis of a central cue relies more on consciously directed, controlled processing. Posner (1980) and Posner and Cohen (1984) make essentially the same distinction between exogenous/peripheral and endogenous/central control of attentional orienting. In the experiments of Jonides (1981) shifts of attention in response to peripheral cues appeared automatic according to several criteria. They made little demand on central capacity, being unaffected by the presence of a secondary memory load - unlike attention shifts made on the basis of central cues. In addition, they were resistant to suppression, and occurred even when subjects were instructed to ignore peripheral cues that provided no information concerning target location.

In an experiment reported by Posner and Cohen (1984) the attentional effects of a peripherally presented cue varied as a function of stimulus onset asynchrony (SOA) between the cue and a simple dot target. At brief SOA's (100ms or less) simple RT was faster for targets appearing on the cued relative to the uncued side. At a longer SOA (500 ms) target detection was slower at the cued location. These effects were termed facilitation and inhibition respectively, and both occurred even though the cue was uninformative with respect to target location; ie. targets were equally likely to occur at cued and uncued locations. In fact the latter were both relatively improbable locations ($p=.1$), since most targets occurred at the centre. The authors attributed these findings to a dynamic balance between two mutually opposed processes. The first of these, giving rise to the facilitation effect observed at brief SOA's, is a tendency for peripheral visual changes to capture attention. However, their views concerning the automaticity of this process were somewhat ambiguous. On the one hand they suggest that peripheral

cues can capture attention independently of target location probability, since the effect "occurs even when the probabilities would favour non-cued locations" (p.549). Indeed, in a previous study (Posner, Cohen & Rajal, 1982) the facilitation effect was observed in a condition where targets were more likely to appear at an uncued rather than at a cued location (p = .8 vs p = .2). Despite this they suggest that "subjects have considerable voluntary control over the facilitation effect" (p.549). Explicit evidence was not provided on the latter point, and indeed at first sight the two proposals appear contradictory.

A number of previous studies have noted the tendency of subjects to pay greater attention to likely target locations (Shaw and Shaw, 1977), particularly when these are indicated by a pre-trial cue (Posner, Nissen and Ogden, 1978; Posner et al., 1980; Eriksen and Yeh, 1985). If the facilitation effect is subject to voluntary control then one would expect subjects to orient attention <u>away</u> from the cue in a situation where target probability favours a non-cued location. Full procedural details were not provided in the Posner et al (1982) report. It is unclear how far subjects were explicitly made aware of the probabilistic relation between cue and target locations. The new experiment reported below attempted to clarify this issue by manipulating both the probabalistic link between one location and target location, and the information and instructions given to subjects. The experiment therefore provided

(1) a further test of the claim that peripheral visual changes capture attention even when targets are more likely to appear elsewhere, and

(2) a test of the degree to which this attentional capture effect is subject to voluntary control.

In Posner and Cohen's study the facilitatory effect was complemented by a later acting inhibitory effect, which was apparent at an SOA of 500ms. It is worth noting here that both the SOA's used by Jonides were relatively short (50ms-125ms). On the basis of further experiments Posner and Cohen suggested that the inhibitory effect is peripheral in nature and that it operates independently of conscious strategies. It was thought that the effect may represent a fundamental visual attentional process that has evolved in order to maximise visual sampling of new environmental locations (see also Maylor and Hockey, 1985).

It is clear from the above that onset of a peripheral display change can produce a complex pattern of spatial attentional effects. The time course of these effects was examined in the present study by varying the SOA between a peripheral cue and a dot target requiring a simple detection response. The work just reviewed suggests that a tendency for attention to be drawn towards the cued location is likely to be observed at very brief SOA's. As indicated above, the experiment attempted to assess the degree of automaticity of this process. This was done in three ways.

First, the claim of Posner and Cohen that the effect can occur independently of target location probability was explicitly

tested; i.e., can the effect occur even when targets are more likely to appear at a non-cued location? Performance was assessed in both an 'uncued probable' condition in which targets were likely to appear on the side opposite to the cue, and a 'cued probable' condition in which targets were likely to appear on the same side as the cue.

Second, the degree of conscious control over the facilitation effect was also assessed by comparing an 'informed condition' in which subjects were given clear information concerning the significance of the peripheral cue for target location, with an 'uninformed condition' in which subjects were not given this information and were instructed to ignore the cue, treating it as an irrelevant display change.

Third, a further test was made of Jonides (1981) proposal that the attention capturing effect of a peripheral cue is capacity free. This was done by including a neutral condition in which the cue consisted of a central, spatially non-informative warning signal. If the process is capacity free one would expect it to be characterised mainly by a relative quickening of detection on the cued side relative to neutral, rather than by a relative slowing of detection on the uncued side relative to neutral. This was considered a fairly tentative test of capacity demand due to the well known problem of devising a perfectly comparable neutral condition (see Jonides and Mack, 1984). It is conceivable, for example, that the general alerting effect of a centrally presented, spatially non-informative warning signal may differ from those of a peripherally presented spatially informative warning signal. Despite this it can at least be predicted that the attentional capture effect at brief SOA's will be characterised predominantly by benefit (i.e., quicker detection on the cued side relative to neutral) rather than cost (slower detection on the uncued side relative to neutral).

Though the inhibitory effect described by Posner and Cohen (1984) was also described as automatic, it was not observed until 500ms after cue onset. This delay would allow sufficient time for any controlled orienting of attention to fully develop. At later SOA's one would expect covert spatial attention to be aligned, under conscious control, with the most likely location for the target. In the cued probable condition this will be the cued location. In previous work (eg. Posner et al., 1978, 1980) aligning attention under conscious control, in response to a central cue, has produced both a beneficial effect on detection at a likely location and a costly effect at an unlikely location, relative to neutral. However, these effects may be overlaid by the inhibitory effect described by Posner and Cohen (1984 - see above), which may operate automatically. In the cued probable condition this would tend to counteract the beneficial effect of paying attention to the cued (ie. likely) location. In the uncued probable condition it would tend to enhance the costly effect of withdrawing attention from the cued (ie. unlikely) location. Hence, at longer SOA's one would expect performance in the cued probable condition to be characterised mainly by cost - relative slowing of detection at the unlikely (uncued) side relative to neutral. In the uncued probable condition there may be both cost - relative slowing at the unlikely (cued) location,

and benefit - relative quickening at the likely (uncued) location. Again, these specific predictions concerning cost and benefit should be regarded as tentative to the extent that the neutral trials may be less than perfectly comparable with peripherally cued trials.

2. METHOD

SUBJECTS: 32 (17 male and 15 female) adult volunteers took part.

APPARATUS: A Hewlett Packard 9845C desk-top computer fitted with a HP 98035A real time clock was used for display presentation and timing.

DISPLAY: The fixation display consisted of three blue outline squares: one on the left of the display, one central and one on the right. A small blue fixation cross was present in the centre of the central square. The sequence of events in a trial is shown in Figure 1.Each square subtended 2.5°. The lateral squares were centred 5° from the fixation cross. A peripheral cue consisted of a transient colour change (blue to yellow then back to blue) in one of the lateral squares. Cue duration was 100ms. On neutral trials (see below) there was a similar colour change in the central square. Targets consisted of a solid white square presented in the centre of one of the lateral outline squares. Targets subtended .3°. Subjects viewed the display from a distance of approximately 55cm.

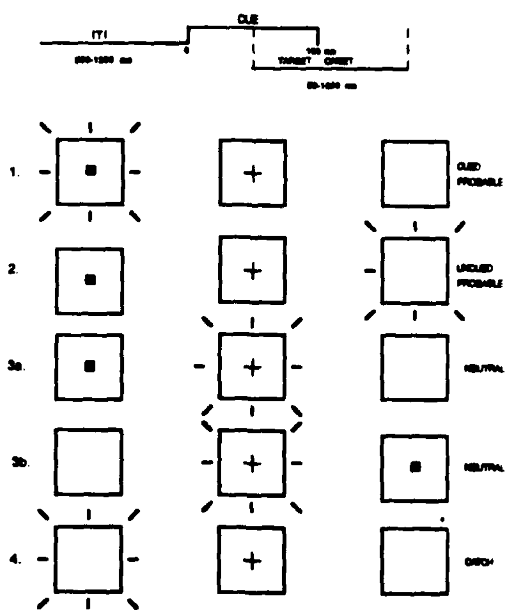

Figure1: Organisation of trials in Experiment 1.

DESIGN: Subjects were randomly assigned to one of four experimental conditions: informed - cued probable, uninformed - cued probable, informed - uncued probable, uninformed - uncued probable. Following presentation of a peripheral cue targets tended to occur on the cued rather than the uncued side in the cued probable conditions ($p=.8$ vs $p=.2$). This contingency was reversed in the uncued probable conditions. In the informed conditions these contingencies were explained to subjects. It was explained that subjects should orient attention towards the most likely location for the target, but the importance of continuing to fixate the central cross was emphasised. In the uninformed conditions subjects were instructed to ignore the peripheral cue, treating it as an irrelevant display change.

Within each of the four experimental conditions just described subjects were presented with four different trial types: on cued trials the target appeared on the same side as the cue; on uncued trials the target appeared on the opposite side to the cue; on neutral trials the colour of the central square changed, and targets were equally likely to occur on either side of the display. On catch trials one of the squares changed colour but no target was presented. Five different SOA's (the delay between cue onset and target onset) were used: 50ms, 100ms, 300ms, 500ms, 1000ms.

Each experimental run consisted of 480 trials presented in three blocks of 160. In all conditions there were 150 neutral and 30 catch trials. In the cued probable conditions there were 240 cued and 60 uncued trials. In the uncued probable conditions there were 240 uncued and 60 cued trials. Within each of the above there were equal numbers of trials at each SOA. The sequence of trials was randomly determined.

PROCEDURE:

Subjects pressed a single key on the computer keyboard following target appearance in one of the lateral squares. Subjects were instructed to make this simple detection response as quickly as possible, but were warned not to anticipate target occurrence. Subjects were instructed to fixate the central cross throughout the experiment, and reminders to this effect were presented at the beginning of each block. At the beginning of each block subjects in the informed conditions were also reminded about the contingent relationship between cue location and target location. At the beginning of each trial subjects fixated the central cross. After an interval which varied randomly between 800ms and 1300ms there was a transient colour change lasting 100ms in one of the three boxes. Following onset of the colour change (cue) a target could be presented in one of the lateral boxes at any one of the five SOA's. On 1/16 trials there was a colour change but no target (catch trials). Depressing the response key caused the target to disappear, and the next trial was begun. If the response key was pressed on a catch trial, or before target onset, or less than 150ms after target onset the computer emitted an 85ms 'beep' to warn subjects that they had anticipated target occurrence rather than responded to it. If there was no response within 1500ms from target onset the trial was terminated and the next one began. Anticipation and

non-response trials were both discarded from analysis. Subjects carried out 40 practice trials before commencing the main experiment.

3. RESULTS

Median response times were calculated for each condition within each block of trials. The data were then collapsed across blocks and entered into analysis of variance with two between groups factors and two within groups factors. The between groups factors were: Location Probability (cued probable vs uncued probable), and Information (informed vs uninformed). The two within groups factors were: SOA (50ms, 100ms, 300ms, 500ms and 1000ms), and Cue Target Relation (cued side vs neutral vs uncued side).

There was a significant main effect of SOA, $F(4,112)=45.61$, $p<.001$, reflecting an overall decrease in latency with increasing SOA. Latencies decreased across the five SOA's (50, 100, 300, 500, 1000) thus: 354ms, 348ms, 341ms, 324ms and 308ms. This is best interpreted in terms of a general alerting effect of the cue. It should be remembered that in addition to conveying location information, the cue also acted as a general warning signal for the next target. The main effect of SOA interacted with Information, $F(4,112)=3.84$, $p<.01$. Subjects given information concerning the significance of the peripheral cues showed a greater warning signal effect than uninformed subjects. This interaction stemmed almost entirely from a much steeper drop in latency between SOA 300 and SOA 500 in the informed group (341ms vs 312ms) compared with the uninformed group (341ms vs 336ms). This effect occurred to a similar extent in both the same probable and opposite probable conditions.

There was a main effect of Cue Target Relation, $F(2,56)=17.63$, $p<.001$. However, the effect of Cue Target Relation entered into several interactions which are displayed in Fig. 1. There was an interaction between Cue Target Relation and Location Probability, $F(2,56)=18.18$, $p<.001$, an interaction between Cue Target Relation, Location Probability and Information, $F(2,56)=3.86$, $p<.05$, and an interaction between Cue Target Relation, Location Probability and SOA, $F(8,224)=2.60$, $p<.01$. Though undoubtedly complex, the data comprising these interactions (shown in Fig 2.) follow a reasonably orderly and theoretically consistent pattern. A number of planned comparisons were carried out in order to answer the questions posed at the outset. These comparisons assessed the effect of Cue Target Relation at different SOA's for the four subject groups and are discussed below.

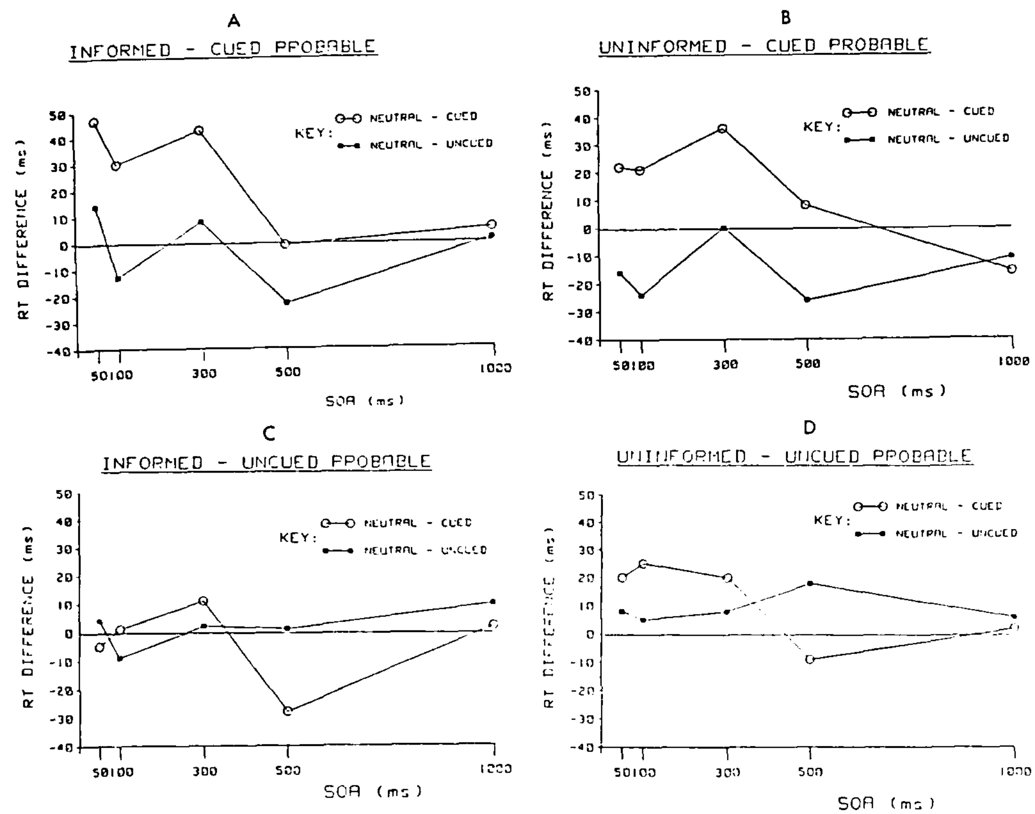

Figure 2: Performance in the four experimental conditions - The distance of each line above or below zero represents the difference in detection latency between the neutral and cued conditions, and between the neutral and uncued conditions. The difference in height between the two lines represents the difference in latency between the cued and uncued conditions.

The data in Fig. 2 are plotted in terms of difference scores. The distance of each line above or below zero represents the size and sign of the difference in latency between the neutral condition and the cued condition, and between the neutral condition and the uncued condition. The difference in height between the two lines represents the difference in latency between cued and uncued conditions. Consider first the three briefest SOA's, 50, 100 and 300. It can be seen from Fig. 1 that there was a tendency for cued side latencies to be shorter than both neutral and uncued latencies in three of the subject groups (informed, cued probable; uninformed, cued probable; uninformed, uncued probable) but not in the fourth (informed, uncued probable). Cued latencies were significantly faster than

neutral latencies in all three SOA's in both the cued probable groups. Similarly, cued latencies were faster than uncued latencies at all three SOAs in both the cued probable groups. In the uninformed, uncued probable group the difference between cued and uncued attained significance at SOA 100 but not at SOA 50 or SOA 300. For the informed, uncued probable group there were no differences between cued, and neutral or uncued latencies at any of the three shortest SOA's.

Consider now SOA 500. The results at this SOA can be summed up thus: In all four groups latencies were significantly slower at the improbable compared with the probable location. In the two cued probable groups, uncued latencies were significantly slower than both cued and neutral latencies, which did not differ from each other. In the informed, uncued probable group cued latencies were significantly slower than both uncued and neutral latencies, which did not differ from each other. In the informed, uncued probable group cued latencies were significantly slower than both uncued and neutral latencies. There were no significant effects at SOA 1000.

4. DISCUSSION

The results suggest that orienting attention towards a peripheral display change is automatic in a sense that is somewhat analogous to the concept of the 'default option' in computer systems: viz. the process will be executed unless there are explicit instructions to the contrary. In the uninformed uncued probable condition detection was facilitated on the same side as the cue at early SOA's, even though the target was far more likely to appear on the opposite side. Hence, the suggestion of Posner and Cohen (1984) that the attentional capture effect can occur even when targets are likely to appear elsewhere has been confirmed. The analogy just given is less than perfect though. Computer operations executed via a default option can be completely over-ridden by alternative instructions. In contrast the ability to over-ride the attention capturing effect of a peripheral cue appears to be less than complete. In the informed uncued probable condition the effect was clearly reduced, but not entirely reversed. Even when subjects were made fully aware of the fact that targets were far more likely to occur on the uncued side latencies remained slightly (albeit non-significantly) faster on the cued side at SOA 100 and SOA 300. Though the levels of practice studied in this experiment were admittedly modest, it is worth noting that suppression of the attentional capture effect did not decrease monotonically across trial blocks, as one might have expected. A close examination of the data showed that if anything there was less suppression of the attentional capture effect in the third and final block than in the first block for both informed and uninformed groups. Indeed, in the final block cued latencies were faster than uncued to a comparable extent in both informed (19ms) and uninformed (23ms) groups in the uncued probable condition at SOA 100ms.

The question of whether the attentional capture effect is automatic in the sense of being capacity free remains equivocal. In general the effect was characterised by a relative quickening

of cued latencies relative to neutral. However, in the cued probable condition the data suggest that this may be accompanied at SOA 100ms by a relative slowing of detection on the uncued side. Theoretically one might attribute this to a consciously directed component of the effect whereby attentional resources are actively withdrawn from the improbable (ie. uncued) location. However, if this were so one would expect to see further increases in the cost associated with the uncued location at SOA 300ms and 500ms. This was not the case. At SOA 300ms the effect was dominated by a quickening of detection on the cued side relative to neutral, with no relative slowing of the uncued side. At SOA 500ms this was completely reversed and the effect was dominated by a relative slowing of the uncued side. It may be that the fast acting attentional capture effect is automatic in the sense of being relatively independent of conscious control, but is nevertheless capacity demanding. The lack of a strong identity between capacity demands and conscious control has been noted in previous work. For example Paap and Ogden (1981) argue that the process of letter encoding is capacity demanding, yet automatic in the sense of being independent of conscious control (see also Kahneman and Treisman, 1984).

Performance at the three briefest SOA's can be summed up thus. Performance was dominated by a tendency to orient attention towards the peripheral display change. This could occur even when targets were far more likely on the opposite side. Under explicit instructions the tendency to orient towards the peripheral display change was reduced, but subjects were unable (at this level of practice) to effect a complete reversal, with attention being rapdily aligned with an uncued but probable location.

At SOA 500 the above pattern was replaced by the more familiar finding that performance was dominated by location probability. In all four conditions detection latency was faster at the likely location compared with the unlikely location for the target. In the two cued probable conditions this effect was characterised mainly by a slowing of the uncued (improbable) location relative to neutral, suggesting a withdrawal of attentional resources from this location. The relative quickening of the cued side relative to neutral was actually much reduced at SOA 500. A plausible interpretation for this pattern is as follows. It may be that the beneficial effect of a consciously directed alignment of attention with the cued location tends to be masked by the inhibitory effect described by Posner and Cohen (1984, see Introduction) which is thought to act automatically. Indeed Posner and Cohen use a closely similar explanation in accounting for the finding that both costs and benefits accrue to likely and unlikely positions when these are reset on every trial with a spatial cue, whereas when location probability is designated over entire trial blocks likely locations show little or no benefit, while unlikely positions continue to show costs (Posner at al., 1980; Posner, Cohen, Choate, Maylor and Hockey, 1984). They argue that repeated stimulation of the likely position in the blocked design leads to a build up of the inhibitory effect. This cancels the beneficial effect of the target appearing at an expected location, while the costly effect of the target appearing at an unexpected location

remains (see also Maylor and Hockey, 1985 for a detailed discussion of this issue).

In the two uncued probable groups detection latency was significantly faster on the uncued relative to the cued side at SOA 500ms. In this case the relative slowing of the cued side compared with neutral may be due partly to the inhibitory effect, thought to operate automatically, and partly to a consciously directed orienting of attention away from the cued (ie. improbable) and towards the uncued (ie. probable) location. This is consistent with the somewhat greater slowing of cued side latencies relative to neutral in the group given explicit information in this condition. On the other hand such an interpretation seems inconsistent with the greater quickening of uncued latencies relative to neutral in the uninformed group. However, as pointed out in the Introduction one should keep in mind the tentative nature of conclusions based on detailed comparisons of cued and uncued latencies with the neutral condition.

Two methodological points could be raised in relation to this experiment. The first concerns possible contamination of the results by eye movements, since eye position was not monitored. Eye position has been monitored in a number of experiments on covert spatial attention reported by Posner and coworkers. Posner et al (1978) found that eye movements greater than 1° occurred on less than 4% of trials, and inclusion of these trials did not in any way change the observed pattern of cost and benefit. Posner et al (1980) report that eye movement monitoring was also carried out in a number of later studies, and that results were not substantially altered by the eye movements that were detected. The use of a simple detection task with clear unambiguous stimuli, presented well above threshold, at an eccentricity of 5°, makes the present study comparable in important respects to a number of experiments reported by Posner and colleagues (Posner et al 1982; Posner and Cohen 1984; Posner et al., 1980). In light of this, the interpretation offered above in terms of attention rather than eye movements seems preferable.

A second methodological issue concerns the effectiveness of the informed vs uninformed manipulation. It might be thought that uninformed subjects would very soon discover the significance of the cues in relation to target location, and as a consequence begin to perform in a manner closely similar to the informed group. This does not appear to be the case. The presence of a significantly greater warning signal effect in the informed group suggests that these subjects did indeed pay closer attention to the cue than uninformed subjects. Interestingly, this distinction between informed and uninformed subjects did not diminish with practice. If anything there was a wider difference in the size of the warning signal effect in the third and final block than in the first block, and this was true of both the cued probable and uncued probable conditions. The above should not be taken to imply an absolute difference between the two groups, ie. that the uninformed group ignored the cue entirely. The warning signal effect, though reduced, remained highly significant. In addition it appears that at SOA 500 both informed and uninformed

subjects were responding to the location probabilities indicated by the cue. For all groups of subjects detection latency at SOA 500 was faster at the likely compared with the unlikely location for the target.

To summarise, presentation of a peripheral cue that was informative regarding target location was accompanied by a complex yet theoretically consistent pattern of results. The data were consistent with a two component view of spatial attentional orienting similar to that proposed by Jonides (1981) and Posner and Cohen (1984). Onset of the peripheral cue tended to produce a fast acting orienting of attention towards the cue. This attentional capture effect appeared relatively automatic since it could occur even when targets were far more likely on the uncued side. However, it was not entirely independent of consciously directed control processes since it was considerably reduced when subjects were explicitly informed that targets were more likely on the uncued side. Although the attentional capture effect was generally characterised by a quickening of detection on the cued side relative to neutral, the data tentatively suggested that this can sometimes be accompanied by a slowing of detection on the uncued side relative to neutral. Hence, the process may not be entirely free of capacity demand. After 500ms the automatic attentional capture effect appears to be over-taken by a slower, more deliberate orienting of attention to the most probable location for the target. In the cued probable condition the effect of consciously aligning attention with the cued location at SOA 500ms may have been masked to some extent by an automatically acting inhibition of detection on the cued side. This may explain why the effect at this SOA was characterised mainly by slowing of detection on the uncued side relative to neutral (cost), rather than by quickening of detection on the cued side relative to neutral (benefit).

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